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LISTS OF SPECIES

Plant species of Okhla Bird Sanctuary: A wetland of Upper Gangetic Plains, India

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ABSTRACT: The Okhla Bird Sanctuary (OBS), a man-modified floodplain wetland having high human impact, is located in an urbanized landscape. Its location in the Central Asian Flyway of migratory birds makes it an ideal transit and wintering ground for birds. This paper describes the vegetation composition and significance of the Sanctuary as a bird habitat. A floristic survey was carried out from winter 2009 to spring 2010 while preparing a management plan for OBS. 192 species of plants belonging to 46 families were recorded from the area. Thirteen species of weeds were observed covering 70% of the sampled area in peak summer. Among trees, highest density was found for two exotic species viz., *Leucaena leucocephala* and *Prosopis juliflora*. The aquatic system is facing threat from proliferation of *Eichhornia cressipes* and *Typha angustifolia*. Strategic eradication of invasive and plantation of native species in the sanctuary are needed for better management.

INTRODUCTION

The Gangetic Plains in India form an important biogeographic zone characterized by fine alluvium and clay rich swamps, fertile soil and high water retention capacity. Around 400 species of angiosperms and 90-120 species of aquatic plants have been recorded from this biogeographic zone. The landscape has the highest human density in India of 800-1200 people per km^2, which has thus resulted in high human impact on natural ecosystems. The Gangetic Plains are scattered with several natural fresh water wetlands. Construction of irrigation canals, tanks, and dams with the primary purpose of irrigation and water supply for domestic purposes has also increased the number of wetlands across the region. In the course of time, these artificial wetlands attracted wildlife and therefore their conservation value has increased. It is estimated that freshwater wetlands alone support 20% of the known range of biodiversity in India (Deepa and Ramachandra 1999). The Okhla Bird Sanctuary (OBS) is one such wetland with a population of 14,000-20,000 water birds of 302 bird species recorded from the Sanctuary and its surrounding areas (Urfi 2003) and provides an example of conservation management of wetlands amidst a densely populated urban area.

Wetlands are often considered as 'hot spots' of biodiversity within a region or a landscape and support unique communities which involve a diversity of plants and animals (Gopal and Sah 1993) and are vastly studied for their functions as a habitat for birds (Stewart 2001). The number of bird species and their diversity is positively correlated with the richness of vegetation in and around a waterbody (Dvork and Best 1982; Andrikovics *et al.* 2006). Stewart (2001) suggested that the selection of habitats by birds depends on factors such as depth and quality of water, the availability of food, presence of vegetation for shelter, presence of predators and inter-species competitors. Vegetation establishes a strong association between aquatic and terrestrial ecosystems in a wetland, and botanical explorations of wetland plants are necessary to gain a comprehensive knowledge about the functioning of the system.

The course of the river Yamuna in Delhi is facing anthropogenic pressure leading to deteriorating water quality and changing water regime (Rawat *et al.* 2003; Aleem and Malik 2005; CPCB 2006; Trisal *et al.* 2008) and has a limited floodplain area because of embankments (Tabasum *et al.* 2009). The OBS has the widest floodplains within this stretch and provides protection to the floodplain habitat because of its status as a Sanctuary. Vegetation studies are fragmentary for the area. A total of 69 species were identified by Tabasum *et al.* (2009) from this stretch (till Okhla Barrage) that includes 39 aquatic and semi-aquatic and 30 terrestrial species. Another study (WII 2002) in OBS recorded 115 plants species belonging to 43 families. Urfi (2003, 2006) described the vegetation of the Sanctuary and surroundings in terms of bird habitat. Currently, a modern and more complete account is lacking despite the above such studies, and in particular a comprehensive list of plants of special relevance for management purposes has remained lacking. During the present study, OBS was under the authority of National Chambal Project Division, Agra, UP and a management plan for the same was being used for OBS, too. A plant checklist of Okhla Bird Sanctuary was prepared along with notes on the population status of some dominant aquatic and terrestrial species to overcome these information gaps.

MATERIALS AND METHODS

Area of study

The Okhla Bird Sanctuary (Figure 1) is a flood plain wetland situated within the National Capital Region of Delhi, India and is part of protected area network of the state of Uttar Pradesh. Construction of the Okhla Barrage

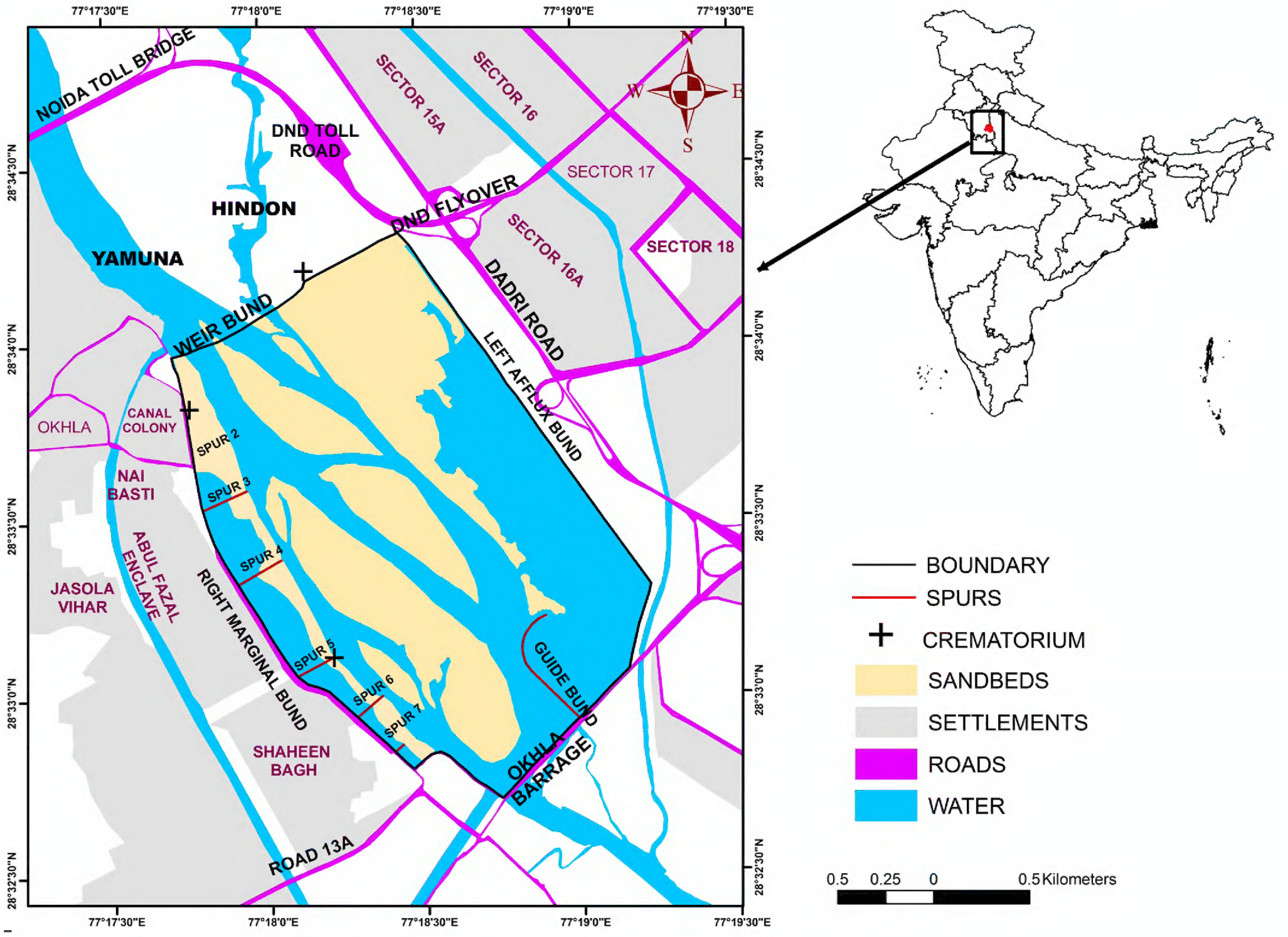

FIGURE 1. Map showing location of the Okhla Bird Sanctuary, National Capital Region, India.

across the river Yamuna has resulted in a small portion of the river to become a static water system. This wetland provides heterogeneous habitat for several migratory waterfowls, of which some species use the wetland as a stopover during their migration. The wetland was declared a Wildlife Sanctuary for Birds on 8 May, 1990 by the Uttar Pradesh government under the Wildlife (Protection) Act, 1972. It has an area of 400 ha with open water covering around 273 ha, reed and sand beds covering 97 ha and roads and bunds comprising the remaining 30 ha area. The area of the Sanctuary is a vast alluvial plain with a gentle southeastern slope. Well-metaled roads surround the Sanctuary and its boundaries are well defined by the mesh-wiring structures and bunds. Sediment of the reservoir is mainly composed of silt load carried by the river Yamuna. Sediment is black in color with slightly alkaline nature. The Sanctuary has mainly three seasons; summer (April-June, temperature range 40°C to 29°C), winter (November-March, temperature range 21°C to 5°C) and monsoon (July-September). In the metropolitan area of National Capital Region of India, this Sanctuary is valuable for recreation and conservation education.

Methods

Extensive floristic survey was performed to cover different micro-habitats in the Sanctuary, which included open water and shallow water areas, islands (sand-beds) within the river channel, floodplains and dykes between winter 2009 and spring 2010. Identification of plants in the field was made with the help of 'The Flora of Delhi' (Maheshwari 1963) and 'Trees of Delhi: A field guide' (Krishen 2006). Unidentified plants were brought to the Wildlife Institute of India (WII), Dehradun for further identification. Collected specimens were cross-checked and identified for correct identification at the Herbarium of WII. APG III (APG III 2009) classification was followed to classify the angiosperm species. To study weeds; all plant species exotic or native (but possessing prolific growth which may hamper the integrity of the ecosystem) were taken into account.

Percent cover for the submerged and floating plant species was estimated visually in 50 x 50 m^2 grids and averaged for the total area to see the extent of weeds. The sand-bed (islands and floodplains) vegetation was divided into upper stratum (mainly reeds) and lower stratum (various herbs). To study the frequency and density of terrestrial vegetation (tree species and amphibious species), 10 ×10 m^2 quadrates were laid at regular intervals of 100 m across the land surrounding the water body and islands.

RESULT AND DISCUSSION

A total of 192 species belonging to 46 families were recorded from the study area with Fabaceae (27 species), Poaceae (19 species), Asteraceae (17 species), Cyperaceae (15 species), Amaranthaceae (13 species), Malvaceae (9

species), Convolvulaceae (8), Euphorbiaceae (7 species), Mimosaceae (7 species), Apocynaceae (7), Polygonaceae (6 species) and Moraceae (6 species) being the richest families, covering over 70% of the total species. Out of 192 species, 33 were trees, 10 were shrubs, 102 were herbs, 19 were grasses, 15 were sedges and 11 were climbers. Among pteridophytes, two species were recorded from the area. One species of a parasitic plant, *Cuscuta reflexa* was also recorded. Detailed vegetation characteristics of OBS are provided in Table 1.

Table 1. List of plant species from the Okhla Bird Sanctuary, National Capital Region of Delhi, Upper Gangetic Plains, India. (H=Herb; C=Climber; S=Shrub; T=Tree; Sd=Sedge; G=Grass; Aq: Aquatic; Tr: Terrestrial; Sm: Semi-aquatic; P: considered weed in present study; N: Considered weed only in previous study (WII 2002); P*: considered weed in both study).

FAMILY/ SPECIES	HABIT	HABITAT	STATUS	VOUCHER NUMBER
Araceae				
Lemna perpusilla Torr.	H	Aq		11912
Spirodela polyrrhiza (L.) Schleid.	H	Aq		11919
Arecaceae				
Phoenix sylvestris (L.) Roxb.	T	Tr		11890
Commelinaceae				
Commelina benghalensis L.	H	Tr/Aq		11921
Commelina forskalaei Vahl	H	Tr		11903
Commelina undulata R.Br.	H	Tr/Sm		11876
Pontederiaceae				
Eichhornia crassipes Solms	H	Aq	P*	11907
Typhaceae				
Typha angustifolia L.	H	Tr/Sm	P*	11928
Typha elephantina Roxb.	H	Tr/Sm	P	11933
Cyperaceae				
Carex alopecuroides D.Don ex Tilloch and Taylor	Sd	Sm		11902
Cyperus bulbosus Vahl	Sd	Tr/Sm		11904
Cyperus compressus L.	Sd	Tr		11923
Cyperus iria L.	Sd	Tr/Sm		11922
Cyperus kyllingia Endl.	Sd	Sm		11905
Cyperus nutans Vahl	Sd	Tr	N	11906
Cyperus triceps Endl.	Sd	Sm		11929
Eleocharis palustris (L.) Roem. and Schult.	Sd	Sm		11924
Fimbristylis cymosa subsp. *cymosa*	Sd	Tr		11937
Fimbristylis dichotoma (L.) Vahl	Sd	Tr/Sm		11935
Fimbristylis ferruginea (L.) Vahl	Sd	Tr/Sm		11909
Fimbristylis quinquangularis (Vahl) Kunth	Sd	Tr		11910
Rhynchospora colorata (L.) H.Pfeiff.	Sd	Tr		11950
Schoenoplectiella roylei (Nees) Lye	Sd	Aq/Sm		11927
Scirpus littoralis Schrad.	Sd	Aq	N	11932
Poaceae				
Arundo donax L.	G	Tr/Sm		11969
Avena sterilis L.	G	Tr		11971
Brachiaria distachya (L.) Stapf	G	Tr		11934
Brachiaria ramosa (L.) Stapf	G	Tr/Sm		11960
Cenchrus ciliaris L.	G	Tr		11982
Cynodon dactylon (L.) Pers.	G	Tr		11961
Dactyloctenium aegyptium (L.) Willd.	G	Tr		11879
Dichanthium annulatum (Forssk.) Stapf	G	Tr		11880
Eragrostis pilosa (L.) P.Beauv.	G	Tr		11881
Imperata cylindrica (L.) Raeusch.	G	Tr		11962
Ischaemum indicum (Houtt.) Merrill	G	Tr		11891
Oplismenus burmannii (Retz.) P.Beauv.	G	Tr		11985
Paspalum distichum L.	G	Tr/Sm		11862
Pennisetum glaucum (L.) R.Br.	G	Tr		11979
Phragmites karka (Retz.) Trin. ex Steud.	G	Tr/Sm		11931
Polypogon fugax Nees ex Steud.	G	Tr		11916
Saccharum bengalense Retz.	G	Tr		11838
Saccharum spontaneum L.	G	Tr		11839
Vetiveria zizanioides (L.) Nash	G	Tr		11958
Papaveraceae				
Argemone mexicana L.	H	Tr	P*	11828

Table 1. ***Continued.***

FAMILY/ SPECIES	HABIT	HABITAT	STATUS	VOUCHER NUMBER
Argemone ochroleuca Sweet	H	Tr		11956
Menispermaceae				
Tinospora sinensis (Lour.) Merr.	C	Tr		11973
Ranunculaceae				
Ranunculus sceleratus L.	H	Tr/Sm		11977
Nelumbonaceae				
Nelumbo nucifera Gaertn.	H	Aq	N	11913
Proteaceae				
Grevillea robusta A.Cunn. ex R.Br.	T	Tr		11811
Oxalidaceae				
Oxalis corniculata L.	H	Tr		11948
Euphorbiaceae				
Acalypha indica L.	H	Tr		11843
Croton bonplandianus Baill.	H	Tr		11878
Euphorbia heterophylla L.	H	Tr		11974
Euphorbia granulata Forssk.	H	Tr		11978
Euphorbia hirta L.	H	Tr		11882
Kirganelia reticulata (Poir.) Baill.	S	Tr		11940
Ricinus communis L.	H	Tr		11855
Cucurbitaceae				
Mukia maderaspatana (L.) M.Roem.	C	Tr		11853
Trichosanthes cucumerina L.	C	Tr		11837
Fabaceae				
Acacia nilotica (L.) Delile	H	Tr		11803
Albizia lebbeck (L.) Benth.	H	Tr		11871
Alhagi pseudalhagi (M. Bieb.) Desv. ex B. Keller and Shap.	T	Tr		11808
Alysicarpus vaginalis (L.) DC.	H	Tr		11976
Bauhinia purpurea L.	T	Tr		11847
Cassia tora L.	H	Tr		11957
Cassia occidentalis L.	H	Tr		11991
Dalbergia sissoo DC.	H	Tr		11972
Delonix regia (Hook.) Raf.	H	Tr		11986
Desmodium triflorum (L.) DC.	T	Tr		11814
Enterolobium barinense Cardenas and Rodriguez	T	Tr		11966
Erythrina variegata L.	C	Tr		11892
Indigofera hochstetteri Baker	H	Tr		11857
Indigofera linnaei Ali	H	Tr		11953
Leucaena leucocephala (Lam.) de Wit	H	Tr		11896
Melilotus alba Medik.	T	Tr		11984
Melilotus indica (L.) All.	H	Tr		11830
Parkinsonia aculeata L.	H	Tr	N	11990
Pithecellobium dulce (Roxb.) Benth.	T	Tr		11988
Pongamia pinnata (L.) Pierre	T	Tr		11856
Prosopis cineraria (L.) Druce	T	Tr		11834
Prosopis juliflora (Sw.) DC.	T	Tr		11849
Rhynchosia minima (L.) DC.	T	Tr		11850
Tamarindus indica L.	T	Tr	P	11946
Tephrosia pumila (Lam.) Pers.	T	Tr		11854
Tephrosia purpurea (L.) Pers.	T	Tr		11975
Tephrosia villosa (L.) Pers.	T	Tr	P	11816
Rhamnaceae				
Zizyphus mauritiana Lam.	T	Tr		11859
Zizyphus nummularia Wt. and Arn.	S	Tr		11822
Ulmaceae				
Holoptelea integrifolia Planch.	T	Tr		11885
Cannabinaceae				
Cannabis sativa L.	H	Tr	P	11868
Moraceae				
Ficus benghalensis L.	T	Tr		11815

Table 1. ***Continued.***

FAMILY/ SPECIES	HABIT	HABITAT	STATUS	VOUCHER NUMBER
Ficus benjamina L.	T	Tr		11865
Ficus palmata Forssk.	S	Tr		11810
Ficus racemosa L.	T	Tr		11851
Ficus religiosa L.	T	Tr		11840
Morus alba L.	T	Tr		11813
Myrtaceae				
Syzygium cumini (L.) Skeels	T	Tr		11819
Salvadoraceae				
Salvadora oleoides Decne.	S	Tr		11944
Cleomaceae				
Cleome viscosa L.	H	Tr		11968
Brassicaceae				
Coronopus didymus (L.) Sm.	H	Tr		11842
Rorippa nasturtium-aquaticum (L.)Hayek	H	Aq/Sm	N	11917
Malvaceae				
Abutilon indicum (L.) Sweet	S	Tr		11801
Bombax ceiba L.	T	Tr		11806
Hibiscus micranthus L.f.	H	Tr		11877
Malva parviflora L.	H	Tr		11895
Malvastrum coromandelianum (L.) Garcke	H	Tr		11992
Sida acuta Burm.f.	H	Tr		11894
Sida cordifolia L.	H	Tr		11817
Sida rhombifolia L.	H	Tr		11818
Urena lobata L.	H	Tr	N	11858
Simaroubaceae				
Ailanthus excelsa Roxb.	T	Tr		11870
Meliaceae				
Azadirachta indica A.Juss.	T	Tr		11872
Melia azedarach L.	T	Tr		11863
Tamaricaceae				
Tamarix dioica Roxb.	S	Tr		11820
Polygonaceae				
Polygonum barbatum L.	H	Tr/Sm	N	11915
Polygonum glabrum Willd.	H	Tr/Sm		11936
Polygonum hydropiper L.	H	Tr/Sm		11926
Polygonum lapathifolia L.	H	Aq/Sm		11845
Polygonum plebeium R.Br.	H	Tr		11970
Rumex dentatus L.	H	Tr		11861
Amaranthaceae				
Achyranthes aspera L.	H	Tr		11848
Alternanthera paronychioides A.St.-Hil.	H	Tr		11827
Alternanthera philoxeroides (Mart.) Griseb.	H	Tr/Aq	P	11900
Alternanthera pungens Kunth	H	Tr/Sm	P*	11804
Alternanthera sessilis (L.) R.Br. ex DC.	H	Tr		11805
Amaranthus tricolor L.	H	Tr		11869
Amaranthus viridis L.	H	Tr		11826
Chenopodium album L.	H	Tr		11852
Chenopodium ambrosioides L.	H	Tr		11941
Chenopodium murale L.	H	Tr/Sm		11920
Gomphrena celosioides Mart.	H	Tr		11987
Pupalia lappacea (L.) Juss.	H	Tr		11875
Suaeda maritima (L.) Dumort.	H	Tr		11833
Nyctaginaceae				
Boerhavia diffusa L.	H	Tr		11873
Basellaceae				
Basella rubra L.	C	Tr		11829
Portulacaceae				
Portulaca oleracea L.	H	Tr		11949

Table 1. ***Continued.***

FAMILY/ SPECIES	HABIT	HABITAT	STATUS	VOUCHER NUMBER
Primulaceae				
Anagallis arvensis L.	H	Tr		11938
Rubiaceae				
Oldenlandia corymbosa L.	H	Tr		11947
Apocynaceae				
Alstonia scholaris (L.) R. Br.	T	Tr		11823
Calotropis gigantea (L.) Dryand.	T	Tr		11874
Cascabela thevetia (L.) Lippold	S	Tr		11836
Dregea volubilis (L.f.) Benth. ex Hook.f.	H	Tr		11824
Oxystelma secamone K.Schum.	C	Tr		11959
Pergularia daemia (Forssk.) Chiov.	C	Tr		11930
Tabernaemontana divaricata (L.) R.Br. ex Roem. and Schult.	C	Tr		11967
Boraginaceae				
Cordia dichotoma G.Forst.	T	Tr		11807
Ehretia laevis Roxb.	T	Tr		11809
Scrophulariaceae				
Kickxia ramosissima Janchen	H	Tr		11886
Mazus pumilus (Burm. f.) Steenis	H	Tr		11888
Acanthaceae				
Blepharis maderaspatensis (L.) B.Heyne	H	Tr		11939
Dicliptera paniculata (Forssk.) I.Darbysh.	H	Tr		11866
Peristrophe paniculata (Forssk.) Brumm.	H	Tr		11945
Rungia pectinata (L.) Nees	H	Tr		11846
Bignoniaceae				
Kigelia africana (Lam.) Benth.	T	Tr		11812
Tecomella undulata (Sm.) Seem.	S	Tr		11860
Verbenaceae				
Lantana camara L.	S	Tr	P*	11893
Phyla nodiflora (L.) Greene	H	Tr/Sm		11914
Convolvulaceae				
Cuscuta reflexa Roxb.	H	P		11832
Ipomoea aquatica Forssk.	H	Aq		11911
Ipomoea arachnosperma Welw.	C	Tr		11864
Ipomoea cairica (L.) Sweet	C	Tr		11884
Ipomoea fistulosa Mart. ex Choisy	S	Tr/Sm	P*	11989
Ipomoea indica (Burm.) Merr.	H	Tr/Aq		11963
Ipomoea sindica Stapf.	C	Tr		11955
Merremia aegyptia (L.) Urb.	H	Tr		11889
Solanaceae				
Datura metel L.	H	Tr		11844
Nicotiana plumbaginifolia Viv.	H	Tr		11983
Solanum nigrum L.	H	Tr		11954
Solanum surattense Burm. f.	H	Tr		11965
Withania somnifera (L.) Dunal	H	Tr		11952
Asteraceae				
Ageratum conyzoides (L.) L.	H	Tr		11802
Cirsium arvense (L.) Scop.	H	Tr		11831
Conyza canadensis (L.) Cronquist	H	Tr		11867
Cotula hemisphaerica Wall. ex Benth. and Hook.f.	H	Tr		11835
Eclipta prostrata (L.) L.	H	Tr		11897
Enydra fluctuans DC.	H	Tr/Sm		11841
Gnaphalium pensylvanicum Willd.	H	Aq/Sm		11908
Laggera aurita (DC.)	H	Tr		11883
Launaea nudicaulis (L.) Hook.f.	H	Tr		11981
Parthenium hysterophorus L.	H	Tr		11887
Pulicaria crispa Sch.Bip.	H	Tr	P*	11964
Soliva anthemifolia (Juss.) R.Br. ex Less.	H	Tr		11898
Sonchus arvensis L.	H	Tr		11951
Tridax procumbens (L.) L.	H	Tr		11943

TABLE 1. ***CONTINUED.***

FAMILY/ SPECIES	HABIT	HABITAT	STATUS	VOUCHER NUMBER
Vernonia cinerea (L.) Less.	H	Tr		11821
Xanthium strumarium L.	H	Tr		11899
Youngia japonica (L.) DC.	H	Tr		11942
Apiaceae				
Centella asiatica (L.) Urb.	H	Tr/Sm		11825
Hydrocotyle sibthorpioides Lam.	H	Sm		11925
Oenanthe javanica (Blume) DC.	H	Tr/Sm		11980
Salviniaceae				
Azolla pinnata R. Br.	Fern	Aq	P	11918
Salvinia auriculata Aubl.	Fern	Aq		11901

The previous study done in 2002 (WII 2002) had recorded 115 plant species belonging to 43 families from the Sanctuary. The major difference in both the lists is in number of herbs (addition of 49 species), tree species (addition of 18 species) and sedge (addition of 11 species). These changes can be attributed to variation in sampling seasons (changes in seasonal herbs) and difference in area covered in both the studies. The fluctuation in water levels of wetland results in difference in submergence of areas during various seasons; moreover, the sand-beds in the middle of the river channel are often submerged in water. This might have influenced the coverage of areas in the Sanctuary during 2002. Recent plantation by New Okhla Industrial Development Authority has also resulted in addition to the Sanctuary's flora.

Wetland plant communities

As the area is a storage water reservoir, water levels fluctuate with season and demand of water. This results in a varying water depth inside the Sanctuary, thus resulting in a number of aquatic vegetation communities in the area. Based on water depth, the Sanctuary had the following plant zones:

Areas with continuous standing water: These areas were largely dominated by two communities, *viz., Eichhornia–Salvinia–Spirodela*, a free-floating plant community and *Nelumbo-Eichhornia,* a floating-leaved community. The former community is widely distributed in the Sanctuary and is dominated by *Eichhornia crassipes,* which forms large monotypic mats over water. At some places, *E. crassipes* was present with *Alternanthera philoxeroides* forming large continuous mats. The later community was restricted to only one location in the Sanctuary, some 30 ha in extent. It was dominated by a single species, *Nelumbo nucifera,* though with presence of *E. crassipes.* In the past, inhabitants of nearby human settlements used this area to harvest lotus fruits and flowers.

Waterlogged areas or areas with shallow water: These had primarily two communities; *Alternanthera–Paspalum–Ipomoea* in relatively shallow water areas and *Phragmites–Typha-Saccharum-Arundo* in waterlogged and draw down areas. Monotypic or intermixed patches of sedges *e.g. Cyperus* spp., *Eleocharis palustris, Schoenoplectiella roylei* were also present. The water body inside the Sanctuary had five islands (sand-beds), which were partially waterlogged and partially dry supporting diverse emergent vegetation communities. These islands had varying water depths, none of which were completely dry during the study. They had plant communities with an upper stratum comprising reeds, sedges and cattail and a lower stratum of herbs, short grasses and other aquatic macrophytes. Reed or tall grass species included *Phragmites karka, Saccharum* spp. and *Arundo donax.* The most abundant species in upper stratum was *Typha angustifolia* forming a continuous closed stand in permanently waterlogged or submerged habitats. This species is not tolerant to dry soils and is very successful in waterlogged conditions. It has colonized many shallower areas with increasing water depth and had the greatest coverage in the Sanctuary (Figure 2). *Typha elephantina* was present in several small patches. *T. elephantina* that flourishes in dry, upland and even saline zones by virtue of deeply-established rhizomes, was usually found nearer to banks. Both the species are common in the floodplains of the river Yamuna. *Saccharum* spp. formed large clumps in comparatively drier areas. *Saccharum spontaneum* is commonly found on alluvial soils and can tolerate infrequent flooding, but never grows in water or frequent flooding regimes (Dabadhagao and Shankarnayana 1973). Accordingly, it remained confined to relatively drier, peripheral areas of the wetland at higher elevation. *Saccharum* spp. formed a community with *Typha* spp., particularly *T. elephantina* in one of the islands. *Phragmites karka* and *Arundo donax* formed either monotypic patches or patches having both the species. Both the species are well adapted to flooding and were abundant in the areas with continuous heavy floods followed by dry phase (Innes 1977; Mackenzie 2004). Sedges present included *Eleocharis palustris, Schoenoplectiella roylei, Carex alopecuroides* and *Cyperus* spp. These formed small monotypic or inter-mixed stands. Sedge like *E. palustris* formed distinct patches in areas with permanent water.

The lower stratum was dominated by *Paspalum distichum* and *Alternanthera* spp. (Figure 3). *Paspalum distichum* grew well both near water and in lower marshy areas. The growth of *P. distichum* is reported to vary depending upon water depth and grazing pressures. In a study in Keoladeo National Park, Middleton (1990) observed maximum growth (shoot density and length) of *P. distichum* in water-saturated soils, though the biomass was greater under flooded conditions. In the Sanctuary, it occurred over a wide water depth. *Alternanthera* spp. were the most frequent among all genera, occurring in 75% plots (Table 2). *Alternanthera sessilis* and *Alternanthera philoxeroides* were the most frequently occurring species. The percent occurrence of the above-mentioned species in

the Sanctuary is given in Table 2. *Ipomoea* spp. were also present in shallow water and dry areas; *Ipomoea fistulosa* being the most frequent in this genera.

Tree species

A total of 33 species of trees had been recorded during current study. *Prosopis juliflora, Leucaena leucocephala, Dalbergia sissoo, Morus alba* and *Zizyphus mauritiana* were most frequent species among the trees observed in the Sanctuary. The frequency and density (individuals ha^{-1}) of major tree species from OBS are given in Table 3. It was observed that *Leucaena leucocephala* had the highest density (192.8 individuals ha^{-1}), followed by *Prosopis juliflora* (142.8 individuals ha^{-1}), *Dalbergia sissoo* (85.7 individuals ha^{-1}) and *Morus alba* (57.1 individuals ha^{-1}). *L. lucocephela* has covered many parts of high ground (mainly embankments such as afflux bund and guide bund) in the Sanctuary. There are many large trees of *L. leucocephala* and thick natural regeneration is seen under and near them. *P. juliflora* grows in some of the high areas on the boundary of the OBS. It is not regenerating independently and hence does not pose much problem currently. A number of trees (both indigenous and exotic) have been planted particularly inside the Sanctuary on the eastern side of the road running on the left afflux bund by the New Okhla Industrial Development Authority e.g. *Alstonia scholaris, Bauhinia purpurea, Melia azedarach*. However, most of these species are not added in the list as the work was in progress during the present study, and nothing can be said with surety regarding the survival of these owing to their early stage.

Invasive plants/weed infestation

Weed infestation has caused major problems for many ecosystems. These plants, often exotic species, grow aggressively and cause changes in the habitat (Janick 1979). Thirteen major weeds were identified in OBS during the study of which five species were amphibious (*Typha angustifolia, Typha elephantina, Alternanthera sessilis, Alternanthera philoxeroides* and *Ipomoea fistulosa*), two were aquatic (*Eichhornia crassipes* and *Salvinia auriculata*) and six were terrestrial (*Parthenium hysterophorus, Lantana camara, Cannabis sativa, Argemone mexicana, Leucaena leucocephala* and *Prosopis juliflora*). A study in 2002 (WII 2002) had recorded 22 weeds from the area. Out of these, 5 aquatic and 1 terrestrial species *viz. Nymphaea nouchali*, *Trapa bispinosa*, *Marsilea quqdrifoliata*, *Utricularia inflexa var. stellaris, Bacopa monnieri* and *Eclipta prostrata*, respectively, were not recorded during current study. There was an addition of 6 new weed species in our list, while 9 species considered weeds in the previous study were not included here, as these did not match the criteria of weeds followed by us (Table 1). At present, OBS is facing threats from the rapid proliferation of *Typha angustifolia* and *Eichhornia crassipes*. About 70% of sample plots in the terrestrial and shallower habitats of OBS were dominated by the species of *Typha*, with approximately 65.88 ha of the Sanctuary covered by *Typha* dominated vegetation. Most of this area was earlier good shallow water habitats for dabbling ducks and waders; a

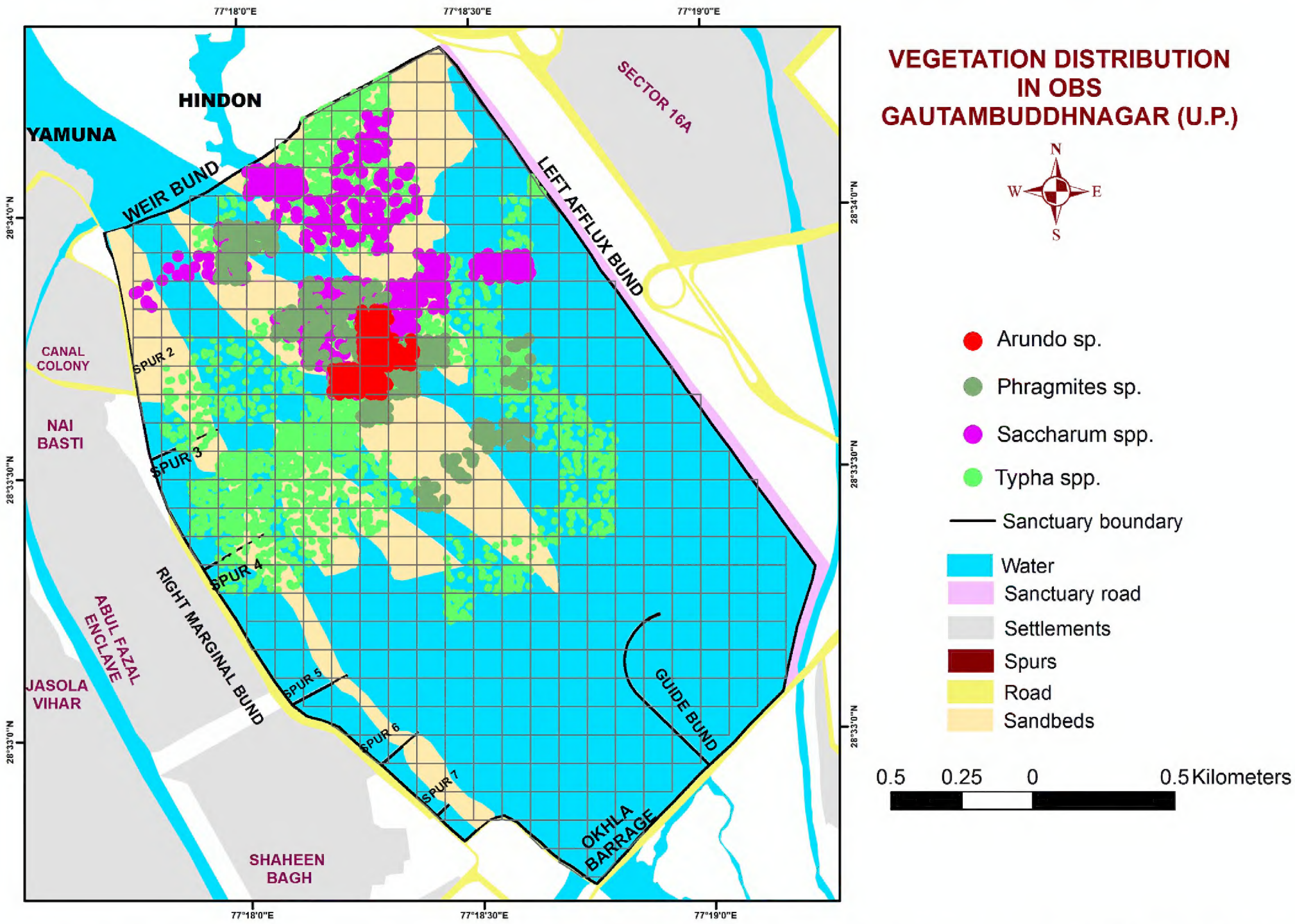

Figure 2. Map showing dominant species of upper stratum in draw-down areas and islands of the Okhla Bird Sanctuary, National Capital Region, India.

habitat which has almost vanished from OBS (personal communication with regular birdwatchers). During the present study, the extent of weeds varied from 20% in December to 70% in May (Figure 4). It was observed that weeds (and particularly aquatic species) proliferated with the advent of the summer season. This may be a function of increased nutrient level in water during summer.

Expansion of aquatic weeds and their highly fluctuating biomass pose threats to habitats of waterbirds and native vegetation. Steps need to be taken to check the ingress of *Typha* into the areas which are still free from it. Certain areas from where *Typha* has to be removed on priority have been identified in the present study and are mentioned in the management plan (WII 2011). These include areas where *Typha angustifolia* has encroached in recent times and areas which were known as shallow habitat for birds in the past. A suggested strategy to remove *T. angustifolia* from these areas is to cut it below the water level, which would lead to dying (rotting) of root stock and should ideally be done in the small post-monsoon time window, well before arrival of winter migratory birds.

Both *Leucaena leucocephala* and *Prosopis juliflora* are exotic species in India. *Leucaena leucocephala* is native to southern Mexico and northern Central America and has now

Table 2. Percent occurrence of major amphibious plant species of the Okhla Bird Sanctuary during current study.

PLANT SPECIES	% PLOTS
Alternanthera spp.	75.0
Typha angustifolia	40.0
Paspalum distichum	33.0
Typha elephantina	30.0
Saccharum bengalense	28.3
Phragmites karka	26.2
Arundo donax	12.4
Saccharum spontaneum	12.2
Ipomoea fistulosa	6.5

Table 3. Major tree species and their frequency (%) and density (individuals ha^{-1}) in Okhla Bird Sanctuary during current study.

FAMILY	SPECIES	FREQUENCY	DENSITY
Mimosaceae	*Prosopis juliflora*	78.6	142.9
Mimosaceae	*Leucaena leucocephala*	35.7	192.9
Fabaceae	*Dalbergia sissoo*	32.1	85.7
Moraceae	*Morus alba*	32.1	57.1
Rhamnaceae	*Zizyphus mauritiana*	25.0	32.1
Meliaceae	*Azadirachta indica*	17.9	17.9
Caesalpiniaceae	*Bauhinia purpurea*	17.9	21.4
Bombacaceae	*Bombax ceiba*	14.3	14.3
Mimosaceae	*Albizia lebbeck*	10.7	39.3
Mimosaceae	*Pithecellobium dulce*	10.7	21.4
Fabaceae	*Erythrina variegata*	7.1	7.1
Moraceae	*Ficus religiosa*	7.1	7.1
Ulmaceae	*Holoptelea integrifolia*	7.1	10.7
Moraceae	*Ficus benghalensis*	3.6	3.6
Bignoniaceae	*Kigelia pinnata*	3.6	3.6
Fabaceae	*Parkinsonia aculeata*	3.6	3.6
Fabaceae	*Pongamia glabra*	3.6	3.6

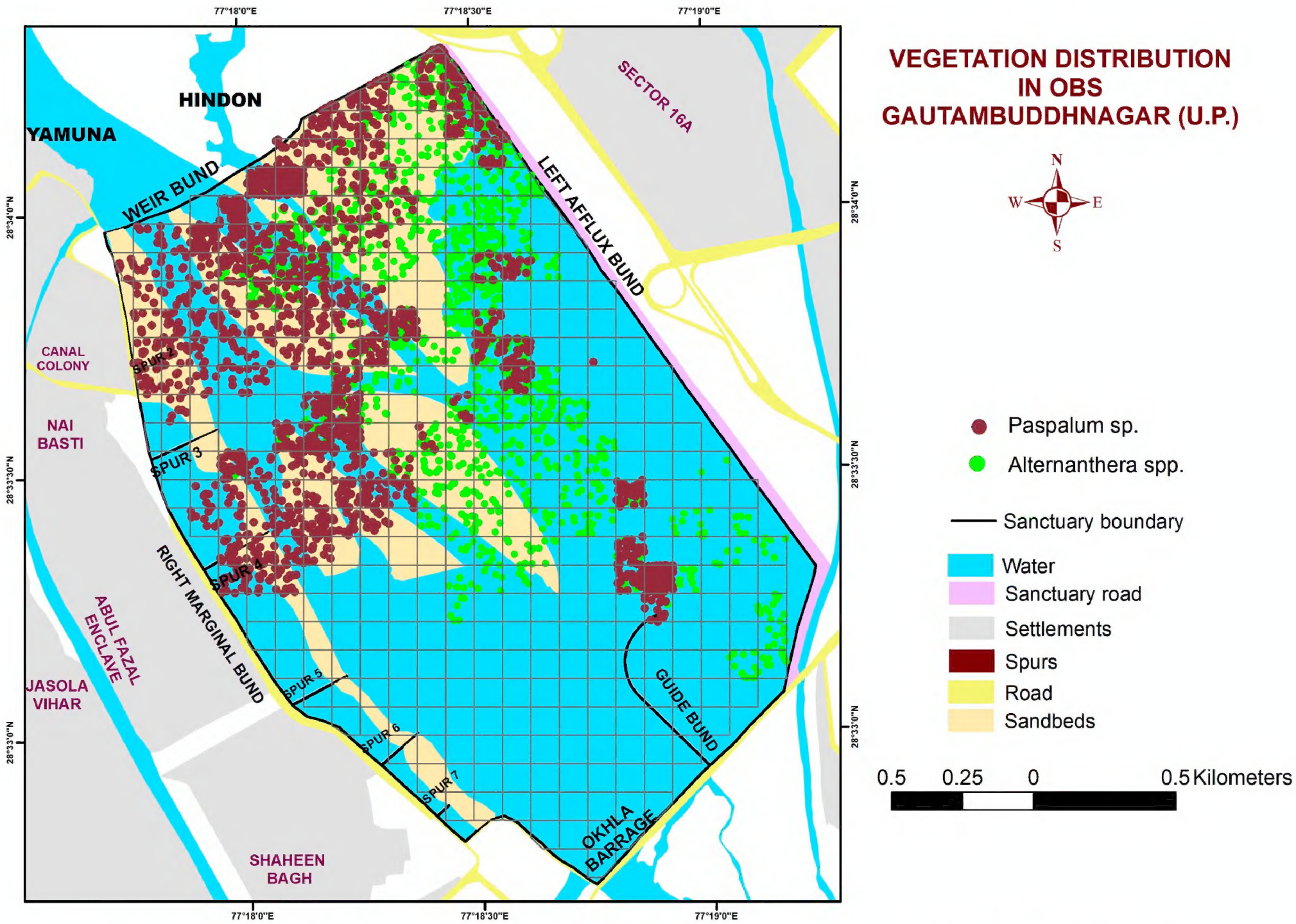

Figure 3. Map showing spread of Paspalum distichum and Alternanthera spp. in the Okhla Bird Sanctuary, National Capital Region, India.

naturalized throughout the tropics. It is highly invasive in the arid climates, growing quickly and resulting in dense thickets which crowd out native vegetation. It is considered one of the 100 worst invasive species by the Invasive Species Specialist Group of the IUCN Species Survival Commission (Global Invasive Species Database 2010). *Prosopis juliflora* is native to Mexico, South America and the Caribbean Islands and has established as a weed in Asia, Australia and elsewhere. It is considered a noxious invader. These species have covered many parts of elevated ground (mainly embankments such as afflux bund, guide bund and spurs on the western bank) in the Sanctuary.

Importance of vegetation in the Sanctuary as bird habitat

A total of 302 species of birds have been reported from the area from several records since 1989 (Urfi 2003). Thus conservation of plant species and communities important for bird nesting and feeding in the area are of prime concern. The Sanctuary has extensive reed beds, shallow vegetated areas, and open deep water habitats. Tall grasses and vegetation like *Phragmites karka, Saccharum* spp., *Typha* spp., and sedges along the wetland and in the drawdown areas provide shelter and protection to bird species like *Anser indicus*, *Tadorna ferruginea*, *Ardea purpurea*, *Pseudibis papillosa*, *Mycteria leucocephala* etc. Presence of extensive reed cover and floating vegetation provides ideal habitat for bird species *e.g. Gallinula chloropus*, *Porphyrio porphyrio*, *Ardea cinerea* and *Ardeola grayii*. Tall grasses and other vegetation act as a buffer against disturbance from roads surrounding the Sanctuary and provide an ideal escape for waterfowl. The *Nelumbo-Eichhornia* community provides a good roosting habitat for waterfowl. However, large, unwanted monotypic stands of *Eichhornia crassipes* and continuous monotypic stands of *Typha angustifolia* have reduced the value of the wetland as good waterfowl habitat.

Grasses like *Brachiaria* spp., *Avena sterilis, Cenchrus ciliaris, Dactyloctenium aegyptium* etc. provide food for the birds of the genera *Lonchura, Prinia, Francolinus* etc., while sedges like *Cyperus* spp., *Eleocharis* sp. etc. also provide food to waterfowl and other birds. Trees like *Ficus* spp., *Morus alba, Syzygium cumini*, *Zizyphus mauritiana, Ehretia laevis, Pithecellobium dulce* etc., herbaceous climbers like *Mukia maderaspatana* etc. and shrubs like *Zizyphus nummularia* are also good sources of food for birds. However, the two most frequent and abundant tree species (*L. leucocephala* and *P. juliflora*) are exotic to the area and indigenous plant species like *Ficus* spp., *Morus alba, Acacia nilotica, Zizyphus* spp. etc. should be planted more in the area. The thick regeneration of *L. leucocephala* needs to be uprooted from most terrestrial areas to eliminate it gradually from OBS. The process of removal of *L. leucocephala* and *P. juliflora* should be done at a later stage once native trees are properly established. No plantations should however be raised on the riverine stretches of the Sanctuary.

Due to a high pressure on floodplain wetlands, the remaining stretches should be recognized as ecologically fragile and included in land-use planning. The role played by native vegetation of the region in maintaining ecological functioning should be integrated in management actions or river restoration plans. Regular monitoring of vegetation change, invasive species extension and its effect on native species should be done. OBS has a mosaic of habitats that is responsible for a rich avifauna. There is a need to monitor these habitats for long-term protection and conservation of various groups of flora and fauna in the Sanctuary. The present findings can be used as a baseline for future studies and a comparison with previous works suggests that steps should be taken to curtail the growth of weeds and plantation of native species should be encouraged.

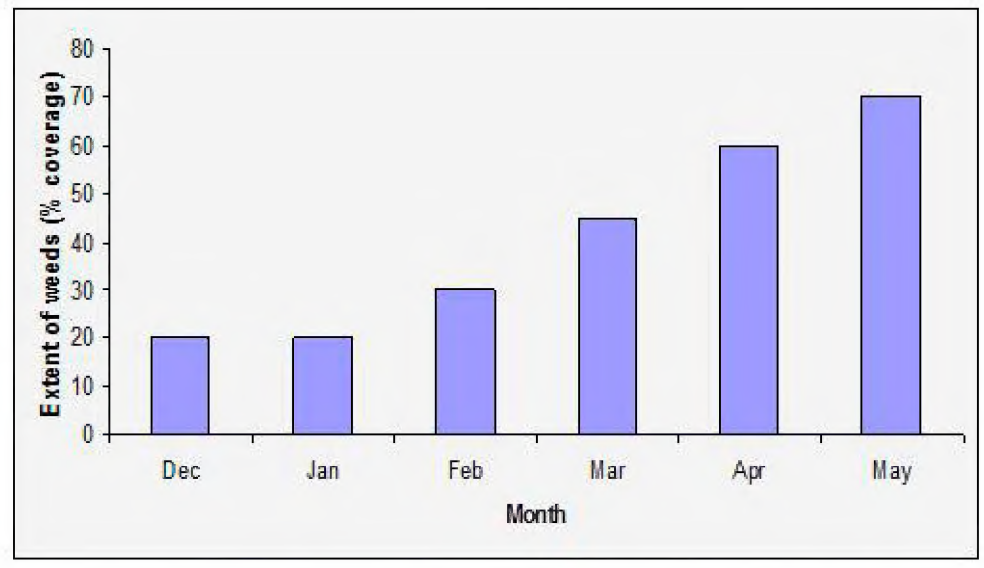

Figure 4. Extent of weeds (% of plots covered) in the Sanctuary in different months between December 2009-May 2010, Okhla Bird Sanctuary, National Capital Region, India.

Figure 5. *Nelumbo - Eichhornia*, a floating-leaved community with reed beds in the background of Okhla Bird Sanctuary, National Capital Region, India.

Figure 6. Reed beds of *Phragmites - Arundo* on one of the islands of Okhla Bird Sanctuary, National Capital Region, India.

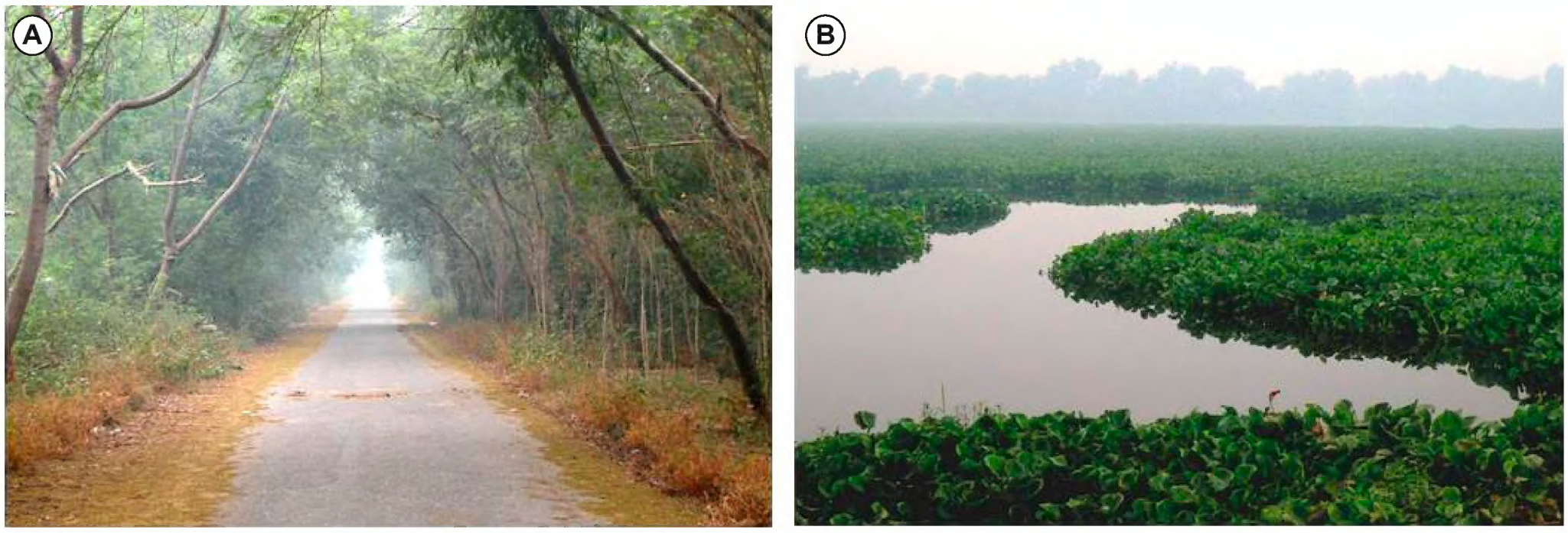

Figure 7. Weed spread in the Sanctuary (A) *Leucaena leucocephala* stand B) Large mats of *Eichhornia crassipes* in Okhla Bird Sanctuary, National Capital Region, India.

Figure 8. (A) *Ficus recemosa* (B) *Pergularia daemia* (C) *Saccharum bengalense* (D) *Cirsium arvense* (E) *Ranunculus sceleratus* in Okhla Bird Sanctuary, National Capital Region, India.

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